A "HIDDEN" DEFICIT IN CENTRAL VISION IN DIABETIC PAN-RETINAL PHOTOCOAGULATION PATIENTS

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Abstract—Adaptation ability in the center of vision was tested in diabetic patients treated with pan-retinal photocoagulation for diabetic retinopathy and in normal control subjects. This was accomplished with a specially designed contrast sensitivity testing regimen. Patients with retinopathy showed "hidden" deficits, losses in adaptation ability that could not be measured by standard clinical tests, such as visual acuity. This new test thus quantifies a previously unmeasured visual problem that affects the everyday visual function of these patients.

Pan-retinal photocoagulation (PRP) has been shown to reduce the risk of blindness in diabetic retinopathy (Diabetic Retinopathy Study Research Group, 1976, 1978). Because treatment is usually confined to the retinal periphery, this ablative surgery often has minimal effect on central vision, as defined by visual acuity (Diabetic Retinopathy Study Research Group, 1976, 1978). However, tests of peripheral visual function have revealed quite noticeable deficits in PRP-treated diabetic persons. Such tests of peripheral function include the EOG and scotopic ERG (Lawwill and O’Connor, 1972), perimetry (Frank, 1975) and dark adaptation (Frost-Larsen et al., 1981).

We recently developed a questionnaire to identify the visual problems that PRP patients experience in their daily lives (Russell et al., 1985). The most common complaint of the thirty-five patients was difficulty in adjusting, or adapting, to changing levels of illumination. Some of the adaptation problems that the patients reported could not easily be explained by the results of the common clinical tests mentioned above. Specifically, although most of the patients retained near-normal visual acuity, they seemed to be experiencing functional deficits that included the central retina.

In order to quantify the central retinal adaptational deficit described by the diabetic patients, we designed a test that quantifies the central retina's ability to adapt. We first measured threshold contrast sensitivity when the patients were well adapted to the moderately low luminance of a test grating. We then re-measured contrast sensitivity very shortly after the subject had been exposed to a moderately bright adapting light. In order to test the patients' adaptation ability under conditions similar to those experienced in everyday life, we used light levels similar to those found in typical environments (Table 1). We tested patients' contrast sensitivity because we wanted measurements that could be related to visual function in various realistic visual tasks. This test of visual function, which examines sensitivity at several spatial frequencies, seems to be well correlated with visual performance outside the laboratory or clinic. In order to emphasize central retinal function, we used a small, centrally presented test grating and included measurements of the contrast thresholds of high spatial frequencies, for which the central retina is specialized.

Table 1. Luminance of typical environments (measured in summertime, Illinois)

<table>
<thead>
<tr>
<th>Surface</th>
<th>Luminance (cd m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staircase, poorly-lit</td>
<td>0.5</td>
</tr>
<tr>
<td>Fire door, well-lit</td>
<td>2</td>
</tr>
<tr>
<td>Test grating in present study</td>
<td>5</td>
</tr>
<tr>
<td>Tile floor, well-lit hall</td>
<td>5</td>
</tr>
<tr>
<td>Desk top, well-lit office</td>
<td>68</td>
</tr>
<tr>
<td>Shaded doorway, sunny day</td>
<td>250</td>
</tr>
<tr>
<td>Adapting source in present study</td>
<td>2000</td>
</tr>
<tr>
<td>Shaded steps, sunny day</td>
<td>2600</td>
</tr>
<tr>
<td>Grass area in sun</td>
<td>2800</td>
</tr>
<tr>
<td>Sidewalk in sun</td>
<td>6800</td>
</tr>
</tbody>
</table>

* Candels per square meter.

METHODS

Our test procedure simulated the rapid adaptation required when a patient goes from an outdoor environment to an indoor setting. Initially, the patient adapted for at least two minutes to the luminance of the test grating (5 cd m⁻², 4.4 × 5.6°). The luminance of the test grating was typical of many common, indoor environments (Table 1). He then made five contrast threshold settings at each spatial frequency. Next, for 2 min, he viewed a uniform adapting field that subtended 9.9 × 14.6°. This bright adapting source had a luminance, 2000 cd m⁻², typical of outdoor settings (Table 1). Then the adapting source was extinguished, and the subject had 5 s in which to make a contrast setting. He then readapted to the adapting source for 10 s, and was given another 5-s interval in which to make a setting. This
cycle was repeated as needed for the subject to complete the test. The timing cycle — adapt, test and readapt — was the same for all experimental runs, except that in half of the runs the bright adapting light remained off.

The patients tested, all males, had all been treated with photocoagulation therapy along guidelines proposed by the Diabetic Retinopathy Study Research Group reports (1976, 1978). They ranged in age from 18 to 40 years. All had visual acuities of 20/40 or better after PRP. Additionally, three out of the five patients (patients PR, AW and RN) had previously reported problems with adaptation on the questionnaire mentioned above. None of the patients showed active intraocular bleeding at the time of testing. Their ocular media were clear or nearly clear. In each case, we tested the eye that the patient felt was his "better" eye. Data were also collected from four non-diabetic, young adult control subjects. All the controls had acuities of 20/20 or better. None had any known ocular disease. The tests on the control subjects were performed in exactly the same way as those on the patients.

Contrast sensitivity was measured with a Nicolet Optronix 2000 Vision Tester. This device displays vertical gratings on a computer-controlled videomonitor, and allows the subject to set contrast visibility thresholds. Contrast sensitivity was tested at 0.5, 1.0, 3.0, 6.0, 11.4 and 22.8 cycles degree⁻¹ of visual angle. The psychophysical method of adjustment was used. The average luminance of the screen (viewed through a neutral density filter) was maintained at 5 cd m⁻² throughout the experiment.

The subjects viewed the screen through natural pupils from a distance of 3 m. Each subject was optically corrected for this distance.

Each subject was given enough practice to become familiar with the task before the tests began. Each subject completed two runs through the spatial frequencies used in each adaptation condition, with five settings at each spatial frequency in each run. To maximize reliability, the median of the five settings was taken as the representative value for each run, and the two medians were averaged to give a single data point in Figs 1–3.

Fig. 1. Left: log contrast sensitivity of diabetic patients treated with PRP. The filled circles represent contrast sensitivity tested while the patient was adapted only to the test luminance; open circles represent contrast thresholds set 5 s after the patient viewed a 2000 cd m⁻² adapting light. Right: same measurements on non-diabetic, untreated control subjects.
One additional diabetic patient was tested for adaptation ability both before and after PRP surgery. First tested several weeks before his surgery, this patient was re-tested approximately three months after surgery. Both his pre- and post-operative testing were as described above.

Detailed perimetric studies, kinetic and static, were done on one PRP-treated diabetic patient (AW). The Goldmann perimeter was used to plot this patient’s isopters, and also to make static perimetry measurements across several visual meridians. Our perimeter was fitted with an electronic shutter so that, during static perimetry, the stimulus was a brief, highly reproducible flash (duration 200 ms, onset time 20 ms). This same patient was also tested with an Octopus automated perimeter. This instrument gives quantitative static thresholds in the central 30° of the visual field, and in a 30–60° annular region. The Octopus testing was carried out with standard methods by a technician at the Coon Ocular Center at Evanston Hospital, Evanston, Illinois.

**RESULTS**

Figures 1 – 3 show the results plotted on logarithmic sensitivity axes (log₁₀). Figure 1 gives the results for four diabetic patients and four controls. First, when well adapted to the test luminance, all of these diabetics have contrast sensitivities within the normal range (filled circles). However, three of the four patients show substantial deficits when required to make contrast settings shortly after viewing the bright adapting light; the exception was patient DL. Only one control subject, LB, shows any sign of a sensitivity loss after viewing the adapting light. We conclude that most of these patients suffer a functional deficit in central vision that is ordinarily “hidden”; that is, it fails to show up in visual acuity measurements or standard contrast sensitivity because such tests are normally carried out under constant lighting.

Patient MD of Fig. 1 was treated with PRP monocularly. Figure 2 displays the results obtained from both his treated eye (left panel) and from his untreated eye (right panel). As before, values on the vertical axis are log₁₀ of contrast sensitivity. Note that when he was well adapted to the test luminance the differences in contrast sensitivity between the two eyes (filled circles) are quite small. However, the PRP-treated eye, but not the untreated eye, suffers a loss in adaptational ability (open circles) at middle spatial frequencies.

The possibility that the adaptational deficit is a side-effect of the PRP treatment (a possibility raised by the results of Fig. 2) led us to test RN, another patient both before and after his PRP therapy. Figure 3 shows the results. This patient, unlike those of Figs 1 and 2, had sub-normal contrast sensitivity even when well adapted to the test luminance (filled circles). He also showed an adaptational deficit both before and after the PRP surgery. However, it is clear that the surgery itself made no difference in his visual abilities as measured by this test.

Consider now the perimetric measurements made on patient AW. Kinetic perimetry, using the Goldmann perimeter, revealed some constriction of AW’s isopters, as has been reported in earlier work (Frank, 1975). Plotting isopters in this way, however, gave little information about central visual function, because the narrowest isopter falls about 10° out from the center of vision. Tests with the Octopus automated perimeter showed many partial and absolute scotomata from about 10° in the periphery and beyond, but gave normal values within the central 10°. Static perimetry, again using the
Goldmann perimeter, suggested that AW had some slight central loss of sensitivity when compared to a normal control.

**DISCUSSION**

With one exception, each diabetic patient showed losses in contrast sensitivity when rapid adaptation was required. Because contrast sensitivity is related to performance in various visual tasks (Leibowitz et al., 1980), it is not unreasonable to expect these patients to experience noticeable visual disabilities when faced with rapidly changing visual environments. Under the same conditions, control subjects showed little or no loss of sensitivity. The sensitivity losses shown in Fig. 1 indicate that some objects otherwise (even large objects) would be rendered temporarily invisible shortly after a PRP patient moves from a typical outdoor setting into an indoor one. Indeed, patients PR and AW had already reported such difficulties in our earlier survey (Russell et al., 1985). Figure 1 shows that no such deficit would be expected from patient DL. We speculate that patient MD notices no problem because he can rely on the eye that shows no deficit.

As with earlier studies (Frank, 1975) the results with these patients vary from one patient to another. However, even from this small sample, the results indicate that this adaptational deficit may warrant consideration as a serious visual disability within this population.

Compared to his untreated eye, patients MD's treated eye shows a deficit in adaptation ability (see Fig. 2). This difference suggests two alternative explanations. First, the adaptational deficit may be a side effect of the treatment itself. Or, the retinopathy might have progressed further in the right eye, thus requiring the surgery in that eye. On this second explanation, the disease, rather than the treatment, caused the deficit.

To see if the PRP actually caused the deficits shown in Figs 1 and 2, we tested patient RN both before and after his surgery. The results (Fig. 3) clearly indicate that the PRP introduced no additional visual disability for this patient. Of course, the lack of a causal relationship between PRP and adaptation problems for one patient does not mean that there is no relationship for any patient, especially since this particular patient had subnormal contrast sensitivity and adaptational abilities before his surgery. All that can be concluded from the current results is that PRP does not necessarily worsen the problem.

Vascular factors such as increased intraocular light scatter, pupillary defects and deficiencies in accommodation might contribute to the adaptation problems shown by the PRP patients. However, there are reasons to believe that none of these is a significant factor in producing these deficits. The fact that the patients had normal contrast sensitivity when adapted to the test grating indicates that any increase in intraocular scattered light was ineffective in lowering sensitivity. (It should be noted that the bright adapting light remained off during all threshold settings, so glare from that light was not a factor.) Although PRP patients often suffer internal ophthalmoplegia (Rogel, 1979), in our sample only PR had markedly abnormal pupils. His small, fixed pupils would decrease the effective retinal illuminance of the test grating, and might reduce contrast sensitivity slightly. However, the fact that his contrast sensitivity was normal when well adapted to the test grating shows that this effect is small.

Finally, the effect of accommodative ability among the diabetic patients must be considered. Our subjects were refracted for the test distance, so no accommodation was required to view the test grating. However, the bright light source was 0.33 diopters closer to the subject than the test grating. So it is possible that the diabetic patients could not adjust quickly enough to the change in accommodative demand. But because the accommodative demand is so small, and because patient MD had a larger deficit at middle than at high spatial frequencies, it can be concluded that accommodation problems could have made only a minor contribution to the adaptational deficits.

It is clear that many of these patients suffer central retinal visual deficits that cannot be assessed by the standard clinical tests. Of the tests we used, only contrast sensitivity after exposure to the bright adapting light (and possibly static perimetry) demonstrated any central visual problem. As pointed out in the Introduction, many of the tests that other investigators have used to measure functional abnormalities in PRP patients have emphasized peripheral retinal function. The only central losses clearly demonstrated in PRP patients by earlier work are changes in color vision (Birch and Hamilton, 1981) and (often slight) losses in visual acuity (Diabetic Retinopathy Study Research Group, 1976, 1978). Another procedure, the “photostress” test, was shown some years ago to give abnormal results in several types of maculopathy patients, including diabetics (Cliforis, 1962; Severin et al., 1967). It is likely that some of our patients would be proven abnormal on this test. But the photostress test is an acuity test, and is thus primarily concerned with visual mechanisms that detect high spatial frequencies (Leibowitz et al., 1980). Because some disease states cause deficiencies in low and middle spatial frequencies while the higher frequency mechanisms remain unaffected, and because different investigators report sensitivity losses in diabetics for different spatial frequencies (Virus et al., 1981) we feel that contrast sensitivity testing is preferable to acuity tests. While some diabetic patients manifest losses in contrast sensitivity taken without rapid adaptation (Della Sala et al., 1985; Ghafour et al., 1982), our results suggest that other patients may have hidden, central deficits that can only be assessed by tests that require rapid adaptation.

**REFERENCES**


